CERTIFICATION REPORT

For

HYDROGLOBE
FerriMet Process

April, 2003

New Jersey Department of Environmental Protection
Division of Science, Research and Technology
Office of Innovative Technology & Market Development
401 E. State Street
Trenton, NJ 08625

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SECTION I

INTRODUCTION

In accordance with the Energy and Environmental Technology Verification (EETV) Act at N.J.S.A. 13:1D-134, the New Jersey Department of Environmental Protection (NJDEP) and New Jersey Corporation for Advanced Technology (NJCAT) have established a performance partnership agreement to identify, evaluate, verify, certify, and expedite the commercial use of innovative environmental technologies (IET) that provide significant net beneficial environmental effect (NBE) to the State of New Jersey. NJCAT performs the technology verification review and NJDEP certifies the NBE of the technology. In addition, the EETV Program establishes the framework for developing a process for providing technical guidance, coordination of the required approvals and reviews, and revision of the regulatory framework affecting the development and commercial use of these technologies.

An IET receiving a certification from the NJDEP results in the following:

1. The programs that issue permits can rely on the evaluation and verification process to establish contract provisions, protocols, policies, principles and/or technical guidance to develop expedited or more efficient timeframes for review and decision-making of permits or approvals associated with the IET;
2. The development and implementation of a series of outreach and education seminars to assist in the deployment and expedited commercial use of the IET; and
3. Working closely with the State Treasurer to be included in State bid specifications, as deemed appropriate by the State Treasurer.

The New Jersey Corporation for Advanced Technology in conjunction with NJDEP, administered a field study of the FerriMet Process. It is a direct coprecipitation filtration process designed to remove heavy metals, such as arsenic, from drinking water to trace levels. The certification of the FerriMet Process is primarily supported by a field pilot study that was conducted at a Hopewell Borough, NJ drinking well and the subsequent verification report prepared by the New Jersey Corporation for Advanced Technology entitled "NJCAT Technology Verification, Hydroglobe, June 2002." The pilot study was funded by the New Jersey Department of Environmental Protection through Stevens Institute of Technology (Stevens), and was conducted in two phases as follows:

1. Phase I included batch and column tests and field pilot filtration tests to:
   a. Determine the need for pre-oxidation and pH adjustment
   b. Establish optimal iron dosage and arsenic removal efficiency
   c. Conduct arsenic speciation

2. Phase II was the field pilot test at Hopewell Borough, NJ to verify the FerriMet process performance for the removal of arsenic from groundwater between December 4 and 23, 2001. The filtration testing was performed in accordance with the EPA/NSF Environmental Technology Verification Protocol – "Protocol for Equipment Verification Testing for Arsenic Removal."

SECTION II

SUMMARY OF VERIFICATION REPORT FROM NJCAT

NJCAT Technology Description

The FerriMet direct coprecipitation filtration process involves injection of small amounts of coagulants (and oxidants if needed) such as ferric chloride into water and subsequent filtration. The system consists of mainly a sand filter and a chemical pump(s). The process is designed to remove heavy metals (e.g., arsenic) from water to trace levels. Ferric chloride injected into the water hydrolyzes rapidly to form ferric hydroxide. The fresh hydroxide has a high capacity for removal of arsenic and other heavy metals through coprecipitation and adsorption. Arsenic is converted from soluble to particulate forms and is subsequently removed by the sand filter. The filters are regenerated by backwash using water. The backwash cycle can be triggered by a pressure drop cross the filter or by a timer.

The innovation of the FerriMet process is the optimization of the conventional coagulation/filtration process. It takes a much smaller footprint area than conventional water treatment processes. The process can also be fully automated which makes it very suitable for small water treatment facilities. FerriMet can be a very cost-effectove solution to arsenic removal compared to conventional iron-based coagulation process and filtration treatment.

NJCAT Verified Claim:

Claim – The FerriMet process has been shown to achieve the reduction of arsenic (including As (III) and As (V)) to below 5 µg/L in groundwater.

The claim was primarily supported by a field pilot study of the FerriMet process at Hopewell, NJ through Stevens Institute of Technology. One of the Hopewell Borough wells, currently not in use, has elevated naturally occurring arsenic (~40 ug/l). According to the speciation analysis performed at Stevens, approximately 10% of the total arsenic was As (III). The majority of the arsenic was As (V), which is less toxic and easier to remove than As (III).

Filtration tests were conducted at Hopewell, NJ to verify the FerriMet process performance for the removal of arsenic from groundwater between December 4 and 23, 2001. A dual-media filter with an inside diameter of 14 inches, a sand bed of 24 inches, and an anthracite bed of 12 inches was used in the filtration tests. The research assistants and engineers from Stevens Institute of Technology conducted the filtration tests. Raw water and filtered water samples were collected and sent to a certified laboratory (Seven Trent Services in Edison, NJ) for analyses of arsenic and general chemical parameters. The optimal filtration conditions established during the Initial Operations phase were: filtration rate of 3.0 gpm/ft^2, ferric chloride dose at 1.5 mg-Fe/l, filtration duration of 48 hours backwash flow rate at about 10.8 gpm/ft^2 for 10 minutes.

The filtration testing was performed in accordance with the EPA/NSF Environmental Technology Verification Protocol – "Protocol for Equipment Verification Testing for Arsenic Removal" (NSF International, 2000). Specifically, the procedures described in Chapter 3 "Coagulation and Filtration for Removal of Arsenic" were followed. The schedules of the tests are listed below. The tests included initial optimization, 24-hr. control filtration run (without chemical treatment), 320-hr. continuous filtration, and 48-hr. filtration at optimal conditions (within 320-hr.). During the field testing, the 48-hr. filtration run lasted for over 90 hr. in order to test a complete filtration run (i.e. reach breakthrough).

NJCAT Verification Testing

During the 48-hour verification testing, the arsenic concentration in the raw water ranged from 33.4 to 39.8 µg/L (commercial laboratory using Inductively Coupled Plasma Atomic Emission Spectroscopy) and from 36.6 to 41.0 µg/L (Stevens Center for Environmental Engineering (CEE) laboratory using Furnace Atomic Absorption Spectrometer). NJDEP personnel sent a split sample taken at 15:30 on 2001-12-19 to an independent state laboratory that reported an arsenic level in the raw water of 41 µg/L and in the filtered water of 3.7 µg/L (Patel & Spade, 2002). The FerriMet process reduced the arsenic concentration to 4.3 µg/L or less (commercial laboratory) or 3.7 µg/L or less, with one exception (CEE laboratory). (Note: The detection limit reported by the certified commercial laboratory was 3.6 µg/L, while CEE estimates an analytical error of ± 50% at an As concentration of 2 µg/L, making the two laboratory results essentially identical.)

Water Treatment Residuals

After 92 hours of filtration, the sand filter was backwashed at a flow rate of 10.8 gpm for 10 min. Based on the total volume of water filtered (16,560 gal) in 92 hrs., the amount of raw water used for the backwash accounted for approximately 0.6% of water filtered. The backwash suspension was collected into a large container to allow the solids to settle for a few days. Approximately 16 L of the thickened suspension was collected. Total suspended solids in the suspension was 11.8 g/L. Soluble arsenic concentration in the suspension was 4.5 µg/L, which indicated that the supernatant could be discharged or pumped back into the filter. The suspension was filtered to remove free water for TCLP testing. Water content in the filter cake was 80%. The arsenic concentration in the TCLP leachate was 3.4 µg/L, which is well below the TCLP limit for a hazardous material. Hence the filter cake is suitable for non-hazardous landfill disposal. Total arsenic content in the dry solids was 8326 mg-As/kg dry solid.

The FerriMet process complexity and costs can be reduced if the backwash can be discharged directly to a POTW. Concerns have been raised about the impact on POTW operations from such a practice. Hence some additional testing on the Hopewell sludge was conducted to evaluate this impact. Specifically the following testing was conducted.

- TCLP on aged sludge (sample received at the commercial laboratory on 4/10/02) to determine if the leaching characteristics could negatively impact POTW sludge disposal. Result – Arsenic concentration in the TCLP leachate was 38 µg/L, well below the limit for a hazardous waste.

- Test of arsenic release from the sludge at pH=9. Results – The soluble arsenic concentration in the liquid was 40.0 μg/L, essentially the same as the untreated well water.

Limitations identified by NJCAT

The removal of As(V) by ferric hydroxide decreases when the water pH increases from 6 to 9. Therefore, pH adjustment is often required when the water pH exceeds 8. The pH adjustment can be achieved by injecting hydrochloric acid in-line into the water prior to the filter. Since ferric hydroxide has a very high removal for As(V), but only a moderate removal capacity for As(III) in this neutral pH range, As(III) should be oxidized to As(V) for efficient arsenic removal.

The presence of high silicate concentration adversely affects the removal of arsenic. Phosphate concentration in the U.S. groundwater is usually less than 0.1 ppm. The existence of phosphorous even at concentrations of less than 1 ppm can dramatically hinder the removal of arsenic. High dose of iron coagulants and pH adjustment may be needed to achieve sufficient removal of arsenic by the FerriMet process when silicate and phosphate anions are present in high concentrations. The FerriMet process also requires a higher dose of iron coagulant, and subsequent higher residuals to manage, as the arsenic concentration in the influent increases.

SECTION III

NJDEP EVALUATION OF HYDROGLOBE'S FERRIMET PROCESS

NJDEP concurs with NJCAT's verified claim that Hydroglobe's FerriMet Process can reduce arsenic to below 5 ug/l in groundwater. The pilot field study conducted at Hopewell Borough, NJ demonstrated the FerriMet Process to reliably remove arsenic levels of approximately 40 ug/l to below 5 ug/l on a consistent basis.

In addition, NJCAT thoroughly identified and evaluated the backwash residuals that were generated utilizing the FerriMet Process. The suspension in the backwash was filtered for TCLP testing and was found to be well below the TCLP limit for a hazardous material. The TCLP results indicate that the solid residuals would be suitable for non-hazardous landfill disposal. NJCAT also evaluated the impacts associated with the direct disposal of the liquid backwash on a POTW. This was determined to be the least costly disposal option. The tests indicated that the backwash concentrated with predominantly insoluble arsenic would collect in a POTW's settling tank and not have an adverse impact to a POTW operation. However, the stringent surface water standards in NJ for arsenic (.017 ug/l) pose an imposing challenge for a POTW to accept arsenic latent backwash from a discharger. In all likelihood a POTW's existing discharge probably does not comply with this standard as natural background conditions can exceed the arsenic standard. It is recommended that a study by NJDEP be conducted to accurately determine background conditions of arsenic in NJ's surface waters.

Finally, NJCAT has demonstrated that the FerriMet Process provides a significant net beneficial environmental effect (NBE) calculating a mass balance of the innovative environmental technology (IET) in terms of its inputs of raw materials, energy use and a qualitative material

balance. With the FerriMet the most important NBE results from removing the arsenic from the drinking water influent and concentrating the arsenic in the filter cake that is ultimately sequestered from direct human intake. The treatment of the arsenic and sequestering it in an insoluble form results in significantly less arsenic available to the environment.

Certification of FerriMet Process

Based on NJCAT's verification report entitled "NJCAT Technology Verification, Hydroglobe, June 2002" and the findings from the pilot field study conducted at Hopewell Borough, the NJDEP hereby certifies Hydroglobe's FerriMet Process as an innovative environmental technology for reducing arsenic (including As (III) and As (V)) to below 5 µg/L in groundwater.

It should be noted that the technology can reduce arsenic to below 3 ug/L with modifications to the filter bed and increase in chemical dosage. The goal to reduce to 5 ug/L was originally selected since that was determined to be a conservative number compared to EPA's standard of 10 ug/L. In addition, the Malcolm Pirnie consultant report prepared for NJDEP supports the fact that coagulation/filtration systems can achieve arsenic concentrations as low as 3 ug/L.